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THE AUTOINSTRUCTIONAL MATERIALS IN THIS TEXT WERE PREPARED FOR USE IN AN EXPERIMENTAL STUDY, OFFERING SELF-TUTORING MATERIAL FOR LEARNING ATOMIC PHYSICS. THE TOPICS COVERED ARE (1) ISOTOPES AND MASS NUMBERS, (2) MEASURING ATOMIC MASS, (3) DISCOVERY OF THE NUCLEUS, (4) STRUCTURE OF THE NUCLEUS, (5) DISCOVERY OF THE NEUTRON, (6) NUCLEAR REACTIONS, AND (7) NUCLEAR MASS AND ENERGY. (RS)

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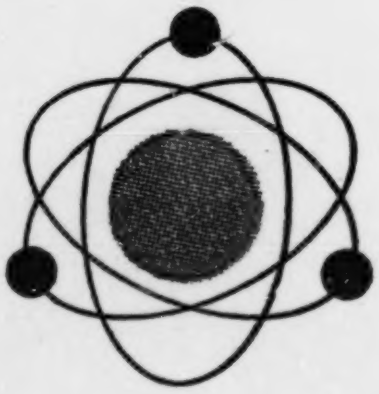
ATOMIC PHYSICS

AN AUTO-INSTRUCTIONAL PROGRAM

David J. Klaus and William A. Deterline

VOLUME 2



AMERICAN INSTITUTE FOR RESEARCH
Pittsburgh, Pennsylvania

ⓘ [redacted]

ATOMIC PHYSICS

VOLUME 2

David J. Klaus and William A. Deterline

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Pittsburgh Pennsylvania

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These materials were prepared for use in an experimental study of the self-tutoring approach in education. Further information concerning the design of the study and the resulting data are contained in reports available from the American Institute for Research.

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Name ______________________

Grade ______________ Age _____

School ______________________

①

UNIT G - Isotopes and Mass Numbers

plus review of Unit F

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rF-13

②

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER G-12

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER G-24

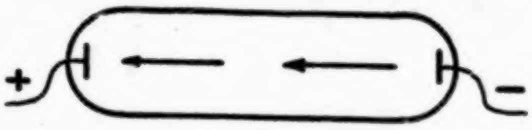
TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER G-36

END OF UNIT

START HERE

③

rF-1 In a cathode ray tube, electrons stream from the ________ to the anode. They occasionally knock ________ ________ loose from atoms of gas in the tube.

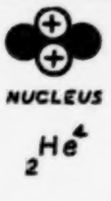


rF-13 Isotopes of the same element have ________ ________ ________ ________.

G-12 Another number used to describe atoms is called the mass number. The atomic number and the ________ number do ________ have the same meaning.

G-24 ${}_2He^4$ is the symbol for the most abundant isotope of helium. The number to the left is the ________ number, indicating that there are two ________ in the nucleus.

G-36 The Z or ________ of an atom indicates the ________ in the nucleus.



rf-12

isotopes
protons
neutrons

④

g-11

atomic number

g-23

carbon
atomic
mass number

g-35

protons (neutrons)
neutrons (protons)
mass (A)

⑤

rf-1

cathode
other electrons (some electrons)

rf-13

nuclei with the same numbers of protons but different numbers of neutrons (the same chemical properties, but have different masses)

g-12

mass
not

g-24

atomic
protons

g-36

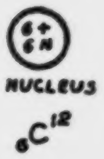
atomic number
number of protons

rF-12 Neon atoms having different masses are called isotopes of neon. Atoms of all ▭ of any one element have the same number of ▭ but may have different numbers of ▭.

⑨

G-11 All isotopes of the same element have the same number of protons. This is the same as saying they all have the same ▭ ▭.

G-23 $_6C^{12}$ is an isotope of carbon. The "C" stands for ▭. "6" is the ▭ number, and "12" is the ▭ ▭.



G-35 The number of nucleons in a nucleus is the sum of the number of ▭ and ▭. The number of nucleons is indicated by the ▭ number.

rF-2 Cathode rays will ionize atoms of gas or air in a cathode ray tube. An atom that has lost one or more of its electrons is called a ______________.

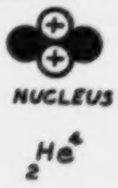
⑦

G-1 Isotopes are atoms of the same element which differ in the number of ______________ in their nucleus. Hydrogen has three different ______________.

G-13 The number of protons in a nucleus is indicated by the ______________, but the total number of particles in a nucleus, that is, both protons and ______________, is indicated by the mass number.

G-25 In the symbol $_2He^4$, the number to the right is the ______________ number, indicating there is a total of ______ particles in the nucleus. These particles include both ______________ ______________.

G-37 The A or ______________ of an isotope indicates the number of ______________ in the nucleus.



rf-11

the same number
neutrons

g-10

protons

g-22

atomic
mass

g-34

nucleons
nucleons (particles is correct, but you should say nucleons)

rf-2

positive ion

⑨

---

g-1

neutrons
isotopes

---

g-13

atomic number
neutrons

---

g-25

mass
4
protons and neutrons

---

g-37

mass number
nucleons (particles)

rF-11 Since all neon nuclei contain ______________________ of protons, neon nuclei of different masses must contain different numbers of ______________.

01

G-10 The atomic number of an element indicates the number of ______________ in the nucleus of an atom of that element.

G-22 The symbol for the most common isotope of neon is ${}_{10}\mathrm{Ne}^{20}$ (say, ten-en-ee-twenty). "Ne" is the chemical symbol for neon, "10" indicates the element's ______________ number, and "20" indicates the isotope's __________ number.

G-34 Protons and neutrons are both called nucleons (new-klee-ons). These ______________ make up the nucleus of an atom and the number of ______________ in an atom is indicated by the atom's mass number.

---

rF-3 A positive ion is an ________ that has ________________________________.

⑪

G-2 There are 92 natural elements, each with a different number of protons. An element is identified by the number of ________ in its nucleus.

G-14 The mass number of an atom indicates the total number of protons and neutrons in the nucleus. Thus, an atom with two protons and two neutrons has a ________________ of four.

G-26 The nuclei of all isotopes of any one element all contain the same number of ________. Therefore, all isotopes of an element always have the same ________ number.

G-38 Most of the mass of an atom is ________________________ of the atom. The nucleons, not the electrons, make up most of the ________ of an atom.

rf-10

not
the same (amount of) mass

g-9

atomic number (number of protons)

g-21

isotope
10
10

g-33

atomic
element (atom, isotope)
the mass number (total number of particles in the nucleus)

rf-3

atom
lost one or more electrons (fewer electrons than protons)

⑬

g-2

protons

g-14

mass number

g-26

protons
atomic

g-38

in the nucleus (contained in the nucleons)
mass

rF-10 Thomson found that all neon ions did [ ] strike the film in the spectrograph at the same point. This indicated that all neon atoms do not have [**].

G-9 Hydrogen has an atomic number of 1; helium has an atomic number of 2. All isotopes of the same element have the same [*].

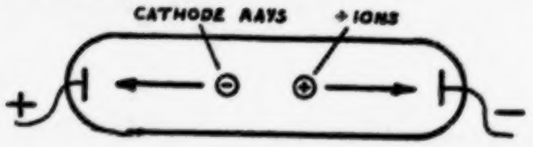
G-21 The element neon has an atomic number of 10. The most common [ ] of neon has a mass number of 20; that is, its nucleus has [#] protons and [#] neutrons.

G-33 The symbol Z indicates the [ ] number of an [ ]. The symbol A indicates [**].

END OF UNIT

⑮

rF-4 In this tube, positive ions will be attracted by the [   ] terminal and will move in an [   ] direction from the cathode rays.



G-3 Every atom of the element carbon has six protons in its nucleus. Thus, the [   ] number of all isotopes of the element carbon is [#   ].

G-15 Two isotopes of the same element always have the same atomic number, but since they have different numbers of particles in the nucleus, they have different [•   ].

G-27 The element carbon has an atomic number of 6. A neutral carbon atom has 6 protons so it must have 6 electrons, since a neutral atom always has [••   ] [   ].

G-39 There are only 92 [   ] found in nature. Each of these [   ] may have several different [   ].

rf-9

film (screen)
greatest (largest)

g-8

number of protons in the nucleus (atomic number)
number of neutrons in the nucleus

g-20

atomic number (number of protons)
mass

g-32

Z
mass number

g-44

cannot be separated chemically
masses (numbers of neutrons)

rf-4

negative
opposite

⑰

g-3

atomic
6

g-15

mass numbers

g-27

the same number of electrons and protons (an equal number of protons and electrons)

g-39

elements
elements
isotopes

rF-9 The mass of an isotope can be studied by observing where its ions strike the [________] in a mass spectrograph. Lighter ions will be deflected the [____________] amount.

(81)

G-8 Isotopes of an element have the same [**________________] [________________________] but different [**________________] [______________________________].

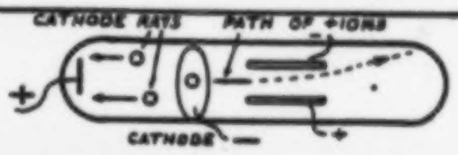
G-20 The number of neutrons in a nucleus can be calculated by subtracting the [*____________________] from the [________] number.

G-32 Although it begins with the letter "a," atomic number is indicated by the symbol [$_____]. The A-number, on the other hand, means [*____________________].

G-44 Elements can be separated chemically but isotopes [*________] [______________________________]. Isotopes can be separated in a spectrograph, however, because they have different [________________].

⑲

rF-5 A beam of positive ions passing through an electric field will be attracted by the ______ plate, because unlike charges ______.



G-4 Isotopes of an element differ in the number of ______ in the nucleus, but all isotopes of the same element have the same ______.

G-16 An atom containing 4 protons and 5 neutrons has a ______ of 9. An atom containing 6 protons and 6 neutrons has a mass number of ______.

G-28 The atomic number of uranium is 92. One isotope of uranium has a mass number of 238. This isotope has ______ protons and it has 238 minus 92, or ______ neutrons in its nucleus.

G-40 Neon is one ______ but it has three ______. All atoms of neon have the same number of ______ in their nucleus but they may have different numbers of neutrons.

rf-8

mass spectrograph
charge
mass

⑳

---

g-7

neutrons
protons

---

g-19

mass number
atomic number

---

g-31

A

---

g-43

isotopes
neutrons

rf-5

negative
attract each other

21

---

g-4

neutrons
number of protons (atomic number)

---

g-16

mass number
12

---

g-28

92
146

---

g-40

element
isotopes
protons

rF-8 In Thomson's ______, the amount of deflection of ions with the same positive ______ will depend upon their ______.

G-7 Isotopes of the same element have different numbers of ______ in their nuclei, but they have exactly the same number of ______ in their nuclei.

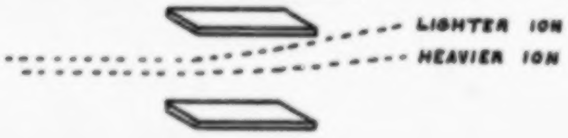
G-19 The total number of particles in the nucleus is indicated by the ______. The number of protons in the nucleus is indicated by the ______.

G-31 The mass number of an isotope is represented by the symbol A. The total number of particles in the nucleus of an isotope is indicated by the ______ number.

G-43 Atoms of the same element which have different masses are from different ______ of that element. Isotopes of an element have different numbers of ______.

㉓

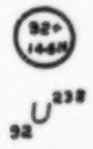
rF-6 Positive ions will be ________ from their path by a magnetic field or by an *________. Heavier ions will be deflected ________ than lighter ions.



G-5 Every atom containing exactly 50 protons is an atom of the element tin. Although tin has 10 isotopes, every atom of every tin isotope has *________.

G-17 Atoms of the same element all have the same ________ number, but different isotopes of that element have different ________ numbers.

G-29 Uranium, ${}_{92}U^{238}$, has an atomic number of #________. It has #________ particles in its nucleus. A neutral ${}_{92}U^{238}$ atom has #________ electrons in orbit.



G-41 Atoms of different elements are different because they have **________ in their nuclei. Isotopes of the same element differ because **________.

rf-7

deflection
masses

---

g-6

cannot be separated from another isotope (of the same element) by chemistry

---

g-18

21
10
11

---

g-30

Z
Z

---

g-42

the same
different isotopes of that element

rf-6

deflected
electric field
less

(25)

---

g-5

50 protons (the same number of protons, the same atomic number)

---

g-17

atomic
mass

---

g-29

92
238
92

---

g-41

different numbers of protons
they have different numbers of neutrons in their nuclei

rF-7 Thomson's mass spectrograph is a special tube used to study the amount of ________ in the paths of ions, and thereby compare the ________ of different positive ions.

(92)

G-6 All the isotopes of any one element are chemically the same. One element can be separated from another element chemically, but one isotope ** ________________________________.

G-18 If an element's atomic number is 10, and its mass number is 21, the nucleus contains a total of # ______ particles. # ______ of these are protons, and # ______ are neutrons.

G-30 The atomic number of an element is called its Z number. In reference tables, a column of atomic numbers is labeled $ ______. All isotopes of an element have the same $ ______ number.

G-42 An atom with 10 protons and 10 neutrons is * ____________ element as an atom with 10 protons and 11 neutrons. However, they are ** ________________________________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rF-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER G-6

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER G-18

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER G-30

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER G-42

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UNIT H - Measuring Atomic Mass

plus review of Unit G

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER H-4

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER H-16

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER H-29

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER H-40

END OF UNIT

START HERE

rG-1 An element is identified by the number of [   ] in its nucleus. All isotopes of the same [   ] have the same [   ] number.

㉛

H-4 When we measure the mass of an atom, we compare its mass to a standard amount of mass. When we measure anything, we [   ] it to a [   ] amount.

H-16 The mass of one atcm of $_8O^{16}$ is exactly [#   ] amu. The mass of an atom of helium is approximately 1/4 the mass of an atom of $_8O^{16}$, thus an atom of helium has a mass of about [#   ] amu.

H-28 Neon, as it occurs in nature, is a mixture of 3 neon [   ], each with the same number of [   ] but with a [**   ].

H-40 In an atom, the number of protons is indicated by the [$] number. The number of electrons in a neutral atom is also indicated by [*   ].

h-3

atomic mass

h-15

atomic mass unit

1/16 of the mass of an $_{8}O^{16}$ atom

h-27

mass

atomic mass units

h-39

electrons

number of electrons

rg-1

protons
element
atomic

(33)

h-4

compare
standard

h-16

16
4

h-28

isotopes
protons
different number of neutrons (in the nucleus)

h-40

Z
the Z number (atomic number)

H-3 To measure the mass of an atom in ______ ______ units, we compare the mass of that atom to a standard amount of mass.

H-15 $_8O^{16}$ is the standard used for measuring atomic mass in amu's. Amu stands for ______. One amu is defined as ______.

H-27 In a mass spectrograph, the isotopes of an element are separated according to their ______, which is measured in amu's. Amu stands for ______.

H-39 Since a neutral atom has as many ______ as it has protons, the Z number indicates the ______ ______ in a neutral atom as well as the number of protons.

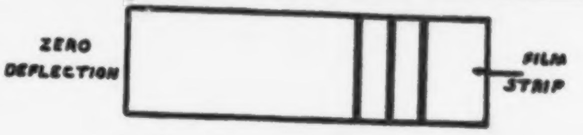
rG-2 Isotopes of the same element differ in the number of ______ in their nuclei, but all isotopes of the same element contain the same number of ______.

(35)

H-5 Hydrogen, $_1H^1$, was once used as the standard amount of mass. The mass of an atom was determined by ______ it with the *______.

H-17 Using $_8O^{16}$ as the standard the mass of iodine, $_{53}I^{127}$ is 126.945 amu. This is very close to its *______ which is #______.

H-29 In the mass spectrograph, atoms of three different ______ of neon each will strike the film at a different point because each of the three isotopes has a *______ ______.



H-41 To find the number of neutrons in $_{27}Co^{59}$, we subtract the $______ number from the $______ number. $_{27}Co^{59}$ has #______ neutrons in its nucleus.

h-2

atomic mass units

---

h-14

atom

1/16 the mass of one atom of $_8O^{16}$

---

h-26

elements

neutrons

---

h-38

number of nucleons (protons plus neutrons) (particles) in the nucleus

mass

---

rg-2

neutrons
protons

---

h-5

comparing
mass of $_1H^1$ (standard amount of mass)

---

h-17

mass number
127

---

h-29

isotopes
different mass (different number of neutrons)

---

h-41

Z
A
32

H-2 The actual mass of an atom is measured in "atomic mass units." These *__________ indicate the total mass of an atom.

H-14 Using $_8O^{16}$ as the standard, 16 amu exactly equals the mass of one __________ of $_8O^{16}$. In other words, one atomic mass unit is equal to **______________________________ __________.

H-26 Most of the 92 __________ that occur in nature have several isotopes. Hundreds of additional isotopes have been made by man by changing the number of __________ in a nucleus.

H-38 The mass number indicates the **______________________________ __________ and only approximately indicates that atom's actual __________.

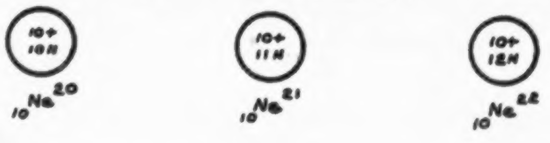
rG-3 The total number of nucleons in a nucleus is indicated by the [ ] number. An $_8O^{17}$ nucleus contains [#] nucleons, of which 8 are [ ], and [*] [ ].

㊴

H-6 The mass of the hydrogen atom is no longer used as the standard. A more convenient [ ] amount of mass, the mass of the oxygen isotope $_8O^{16}$ is now used.

H-18 The mass of nitrogen, $_7N^{14}$, is 14.0075 amu. This is very close to its mass number of [#].

H-30 The nuclei of the 3 neon isotopes are represented in the figure. The most abundant neon isotope is $_{10}Ne^{20}$. An atom of $_{10}Ne^{20}$ has a mass of approximately [#] atomic mass units.



H-42 One isotope of sulfur is $_{16}S^{34}$. A $_{16}S^{34}$ nucleus contains [#] nucleons, of which [#] are protons and [#] are neutrons.

h-1

not

---

h-13

mass

mass

one atom

---

h-25

protons

neutrons

---

h-37

Z

A

greater (larger)

---

rg-3

mass
17
protons
9 are neutrons

h-6

standard

h-18

14

h-30

20

h-42

34
16
18

H-1 The mass number indicates the number of nucleons in an atom, but the mass number does [ ] tell us the actual mass of the atom.

H-13 Atomic mass units are used to measure the [ ] of atoms. One amu is equal to 1/16 of the [ ] of [*] [ ] of $_8O^{16}$.

H-25 The main difference between atoms of different elements is in the number of [ ] in their nuclei. Isotopes differ because they have different numbers of [ ] in their nuclei.

H-37 The symbol for atomic number is [$], and the symbol for the mass number is [$]. Except for hydrogen, $_1H^1$, the mass number is always [ ] than the atomic number.

rG-4 The atomic number of an atom indicates the number of ☐ in a nucleus. The mass number indicates the number of ☐ plus ☐.

㊸

H-7 If 1/16 of the mass of the ${}_{8}O^{16}$ isotope of oxygen is used as a standard, the mass of every atom, in atomic ☐ units, is very similar to its mass number.

H-19 Knowing that the mass number of aluminum, ${}_{13}Al^{27}$ is #☐, you know that the actual mass of ${}_{13}Al^{27}$ is approximately #☐ amu.

H-31 Most of the mass of an atom is in its ☐. Nuclear particles, that is both protons and neutrons, are called ☐.

H-43 ${}_{82}Pb^{206}$ is one of the ☐ of the element lead. It has #☐ protons, #☐ neutrons, and a neutral ${}_{82}Pb^{206}$ atom has #☐ electrons.

rg-9

23

$_{11}\text{Na}^{23}$

h-12

mass

16

h-24

1/16 of the mass

16

h-36

nucleons

nucleons

number of protons (in the nucleus)

rg-4

protons
protons (neutrons)
neutrons (protons)

④⑤

---

h-7

mass

---

h-19

27
27

---

h-31

nucleus
nucleons

---

h-43

isotopes
82
124
82

rG-9 Sodium, symbol Na, has only one natural isotope. Its nucleus contains 11 protons and 12 neutrons. The total number of nucleons is #______, and the complete symbol is $______.

H-12 One amu is equal to 1/16 of the ______ of one atom of $_8O^{16}$. In amu's, one atom of $_8O^{16}$ has a mass of #______ amu.

H-24 One amu is equal to **______ of an atom of $_8O^{16}$. The mass of $_8O^{16}$ is #______ amu.

H-36 Particles in the nucleus are called ______. The A number indicates the number of ______ in the nucleus, but the Z number indicates only the **______ ______.

---

rG-5 $_6C^{12}$, $_6C^{13}$, and $_6C^{14}$ are ________ of the ________ carbon. Every carbon nucleus contains exactly ________. A neutral carbon atom has ________ ________ in orbit. ㊼

H-8 Atomic masses based on $_8O^{16}$ as the standard are used because then the mass measured in ________ is almost the same as the atom's ________ number.

H-20 The actual mass of an atom is approximately the ________ as the ________ number of that isotope.

H-32 Protons and neutrons each have a mass of approximately 1 amu. Amu stands for ________.

H-44 $_1H^1$ is one of the ________ of the ________ hydrogen. It has ________ proton and ________ neutrons in its nucleus.

rg-8

nucleons

number of protons (atomic number)

Z number from the A number (number of protons from the number of nucleons)

---

h-11

1/16

---

h-23

the same as the mass number of that isotope

---

h-35

atomic

mass

---

rg-5

isotopes
element
6 protons
(49) 6 electrons

---

h-8

atomic mass units
mass

---

h-20

same
mass

---

h-32

atomic mass unit

---

h-44

isotopes
element
I
0 (zero)

rG-8 A is the symbol for number of ____________, and Z means the * ____________. To determine the number of neutrons, you would subtract the ** ____________ ____________.

10+
11N
$_{10}Na^{21}$

H-11 To establish the standard we now use, the mass of one $_8O^{16}$ atom was set at 16 amu. Therefore, one amu is equal to # ______ of the mass of one $_8O^{16}$ atom.

H-23 When $_8O^{16}$ is used as the standard, the mass of an atom of any isotope in amu's is approximately ** ____________ ____________.

H-35 Physicists use the symbols $_ZE^A$, as in $_6C^{12}$ or $_{10}N^{20}$. The letter Z is the ________ number and the letter A is the ________ number.

(51)

rG-6 Nucleons are the protons and neutrons in a nucleus. $_{10}Ne^{20}$ contains a total of 20 ______. 10 are protons, and ______ are neutrons.

H-9 The mass of an atom in atomic mass units is almost the same as its •______ when $_8O^{16}$ is used as the standard.

H-21 When 1/16 of the mass of $_8O^{16}$ is used as the standard, the actual ______ of an atom in amu's is almost the same as its ______ number.

H-33 Every element has an atomic number, which indicates the ••______.

END OF UNIT

rg-7

mass number
protons
number of nucleons (protons and neutrons)

h-10

atomic mass

h-22

23

h-34

the same atomic number (same number of protons)

rg-6

nucleons

10

h-9

mass number

h-21

mass

mass

h-33

number of protons in the nucleus (number of + charges in nucleus)

(54)

rG-7 The Z number is the atomic number and the A number is the * ____________. Z indicates number of ____________ and A indicates the ** ____________ ____________ in a nucleus.

H-10 It was decided that the mass of an atom of $_8O^{16}$ would be used as the standard to define atomic mass units (amu). The mass of $_8O^{16}$ was defined as being exactly 16 * ____________ units.

H-22 Some sodium atoms have a mass of 22.997 amu. You can guess that this isotope has a mass number of * ____.

H-34 All isotopes of the same element have ** ____________ ____________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rG-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER H-10

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER H-22

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER H-34

END OF UNIT

UNIT I - Discovery & the Nucleus

plus review of Unit H

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number I. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

58

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 1-4

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 1-18

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 1-32

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER 1-46

END OF UNIT

START HERE

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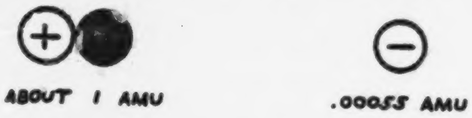
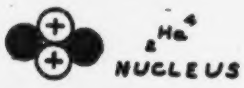
rH-I Electrons have very ______ mass compared to protons and neutrons. Thus, most of the ______ of an atom is in the ______.

I-4 Nucleons, which are the ** ______ ______, each have about 1840 times as much mass as an electron; thus, most of the mass of an atom is in the ______.



I-18 Wide deflections appeared in the paths of positively charged particles shot through atoms. These wide deflections would not have occurred if the ** ______ ______.

I-32 A $_2He^4$ atom, with both its electrons removed, is simply the ______ of the helium atom. This doubly ionized particle is called an * ______.



I-46 Early experimenters shot * ______ at the targets because they were the only high velocity particles available at the time. They used gold foil as the ______.

i-3

protons
neutrons
mass

i-17

deflect (repel)
its original path (the nucleus)

i-31

2
electrons
nucleus

i-45

scattering

rh-l

little
mass
nucleus

(61)

---

i-4

protons and neutrons in a nucleus (atomic particles in the nucleus)
nucleus

---

i-18

charges were evenly distributed in an atom

---

i-32

nucleus
alpha particle

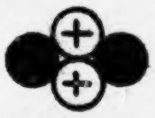
---

i-46

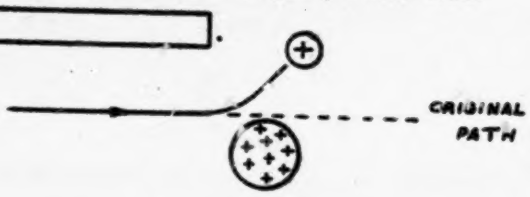
alpha particles
target

㉙

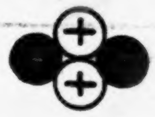
I-3 A nucleus contains both positively charged ☐ and neutral or uncharged particles called ☐. Both of these particles have approximately the same amount of ☐.



I-17 An atom which had a concentration of positive charges at its center would ☐ a positively charged particle from ☐ **.



I-31 A neutral helium atom has 2 protons 2 neutrons and ☐ # electrons in orbit. A doubly ionized $_2He^4$ atom has no ☐ orbiting around its ☐.



I-45 Today many different kinds of particles can be used to study scattering. The pattern in which particles passing near nuclei are deflected is called ☐.

END OF UNIT

rH-2 The mass number of an atom indicates the total number of ________ in the nucleus. Most of the mass of an atom is ** ____________________.

I-5 As you remember, Thomson and Millikan studied only one kind of atomic particle, the ________. The nucleus and its particles had not yet been identified.

I-19 When positively charged particles are shot through atoms, ** ____________________ from their paths.

I-33 An alpha particle is a doubly ionized ________ atom. Thus, an alpha particle is only the ________ of a ________ atom.

I-47 Gold foil was used as the target in early experiments because it can be made into very thin sheets. Now it is possible to use other elements as the ________ in a ____________ experiment.

i-2

negative
positively

---

i-16

would
repel

---

i-30

alpha particle

---

i-44

alpha particles
deflected (scattered)

---

i-58

no
small

rh-2

nucleons
in the nucleus

(65)

i-5

electron

i-19

they will be deflected

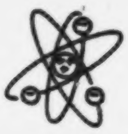
i-33

helium
nucleus
helium

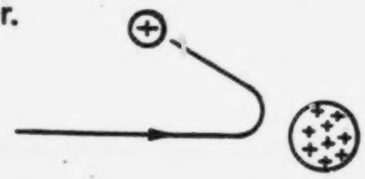
i-47

targets
scattering

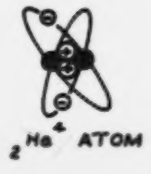
I-2 In an atom, the orbiting electrons have a ______ electrical charge and the nucleus contains all of the ______ charged particles.

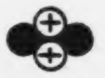


I-16 If an atom did have a tight concentration of positive charges at its center, a positively charged particle ______ be deflected because like charges ______ each other.

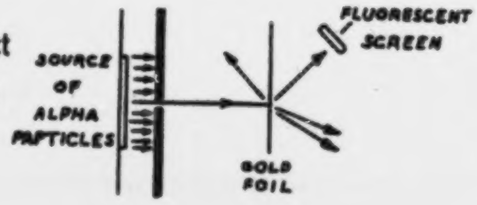


I-30 As shown in the figure, a doubly ionized helium atom is called an ______.




ALPHA PARTICLE ($_2He^4$ NUCLEUS)

I-44 A stream of ______ was shot through gold foil. A fluorescent screen placed to one side was used to detect outcoming particles which had been ______.



I-58 Most of the space occupied by an atom is "free space" which contains ______ matter at all. The nucleus of an atom is very ______, even in comparison to the size of an atom.

rH-3 The actual mass of an atom is measured in "atomic mass units." These *__________ indicate the total mass of an atom.

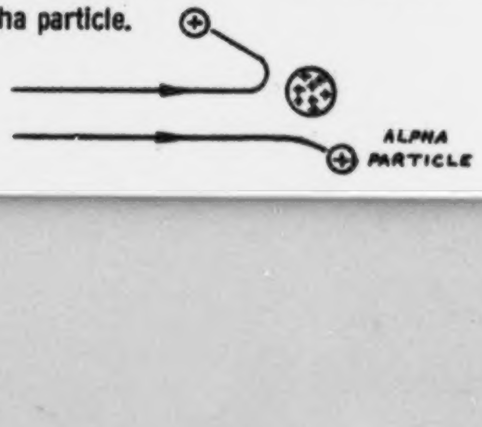
(67)

I-6 After the electron was discovered, physicists tried to learn more about the structure of the atom, but because an atom is so ______, it is impossible to see its structure directly.

I-20 Positively charged particles shot through atoms are deflected because they are ______ by the **__________ __________.

I-34 We use the symbol ${}_2He^4$ to represent atoms of the element ______. The symbol also means just the nucleus of ${}_2He^4$, which is called an *__________.

I-48 The closer an alpha particle passes a nucleus in the target, the more the like charges will ______ each other and the greater the ______ of the alpha particle.



i-1

nucleus
electrons

i-15

deflected
evenly distributed throughout the atom

i-29

2
no

i-43

alpha particles ($_2He^4$ particles)
target (gold foil)

i-57

nucleus
atom
electron

rh-3

atomic mass units

(69)

---

i-6

small

---

i-20

repelled

positive charges in the nucleus (at the center of the atom)

---

i-34

helium

alpha particle

---

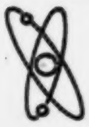
i-48

repel (effect)

deflection (scattering)

OL

1-1 Physicists learned less than 60 years ago that an atom consists of a central core, which is called a ________, and orbiting particles called ________.



1-15 A charged particle moving through an atom would not be ________ very much if charges were ________ ________.

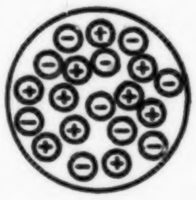
1-29 An alpha particle is a doubly ionized $_2He^4$ atom. A neutral $_2He^4$ atom has ____ electrons; a doubly ionized $_2He^4$ had both electrons removed and has ____ electrons left.

1-43 In their experiments, Geiger and Marsden used thin gold foil as a "target." They shot ________ at the foil to study scattering as they passed through the atoms in the ____.

1-57 The diameter of a ________ is only 1/10,000 of the diameter of the entire ____. If the nucleus was the size of a golf ball, the closest ________ in orbit would be about 4 city blocks away.

rH-4 The standard used to determine actual mass is $_8O^{16}$, an isotope of [   ]. 1/16 of the mass of an atom of $_8O^{16}$ is equal to [••   ].

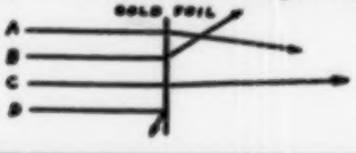
I-7 At first it was thought that an atom was a solid lump of positive and negative charges, that is, the charges were all mixed together and there was no [   ] at the center.



I-21 Geiger and Marsden were among the first physicists to fire particles through [   ]. They discovered that all the positive charges in atoms are [••   ] [   ].

I-35 The symbol $_2He^4$ means an [   ] of the element helium. We also use the symbol [$] to represent an alpha particle.

I-49 Some possible paths in the scattering of alpha particles are shown in the figure. Very wide deflections like lines [$] and [$] would not occur if atoms in the target had evenly distributed charges.



rh-II

nucleons
nucleons
atomic mass units

i-14

not

i-28

electrons
lost 2 of its electrons

i-42

scattering
alpha particles
atoms

i-56

nucleus

rh-4

oxygen

one atomic mass unit

(73)

---

i-7

nucleus

---

i-21

atoms

concentrated at their centers (concentrated in nuclei)

---

i-35

atom (nucleus)

${}_{2}He^{4}$

---

i-49

B

D

rH-11 Both the protons and neutrons in a nucleus are called ________. The mass number indicates the number of ________ and is approximately equal to mass measured in * ________________.

1-14 Since the forces on it would be equal from all directions, a positively charged particle passing through evenly distributed charges would ______ be deflected very much.

1-28 An atom that is singly ionized has lost one of its ________. An atom which is doubly ionized has ** ________________.

1-42 The Geiger and Marsden experiments are called ________ experiments, because their main objective was to study the deflection of * ________________ as they passed through ______.

1-56 Rutherford calculated the size of the area in which the positive charges were concentrated, that is, the size of the ______. He found it was only about $^1/_{10,000}$ the size of the whole atom.

rH-5 One ______ of the oxygen isotope, $_8O^{16}$, has a mass of 16.000 amu. 1/16 of the mass of an $_8O^{16}$ atom is equal to ______ amu.

(75)

1-8 The way charges are actually distributed in an atom was discovered by shooting positively charged particles through an atom. This method makes use of the principle that like charges ______ each other.

1-22 We now call the concentration of ______ ______ at the center of an atom the ______.

1-36 An alpha particle is ______ ______.

1-50 Since atoms have a concentration of ______ ______ at their center, an alpha particle would sometimes be widely ______.

rh-10

isotopes

mass

amu

approximately 21 amu

i-13

the forces tending to move it any other way

i-27

ion

i-41

scattering

i-55

positive charges in an atom are concentrated in the nucleus (positive charges are not evenly distributed)

rh-5

atom (nucleus)

I

---

i-8

repel

---

i-22

positive charges

nucleus

---

i-36

a doubly ionized helium atom ($_2He^4$ nucleus)

---

i-50

positive charges

deflected (scattered)

rH-10 Neon has three ________, each with a different ________. The mass of $_{10}\mathrm{Ne}^{20}$ is approximately 20 $ ________, and the mass of $_{10}\mathrm{Ne}^{21}$ is ** ________.

I-13 If a positively charged particle passed through evenly distributed charges, the forces tending to move it one way would be no greater than ** ________.

I-27 An atom is ionized when it loses one or more of its electrons. An atom that has lost electrons is called a positive ________.

I-41 The deflection of particles passing through atoms is called "scattering." Thus, the pattern of deflection of alpha particles in the Geiger and Marsden experiments is called ________.

I-55 Scattering experiments have furnished information on the structure of the atom, since large deflections in the paths of alpha particles indicated that ** ________.

rH-6 The mass number of $_{11}Na^{23}$ is ☐. Its actual mass in atomic ☐ is approximately equal to the ☐ number.

(79)

I-9 If a positively charged particle passed through an area full of both positive and negative charges, it would be ☐ by the positive charges and ☐ by the negative charges.

I-23 The kind of positively charged particle used by Geiger and Marsden is called an alpha particle. They bombarded atoms with ☐.

I-37 Alpha particles are emitted at high speeds from radioactive substances. An alpha particle is a ☐ nucleus, with a ☐ electrical charge of 2.

I-51 Alpha particles would not be ☐ deflected in scattering experiments if charges were evenly ☐ throughout the target atom.

rh-9

23

(08)

i-12

evenly

equal (the same)

i-26

4

2

2

i-40

atom

positively (like)

atom

i-54

not

distributed

rh-6

23
mass units
mass

---

i-9

repelled
attracted

---

i-23

alpha particles

---

i-37

$_2He^4$ (helium)
positive

---

i-51

widely
distributed

rH-9 Sodium atoms have an actual mass of 22.997 amu. The mass number of this isotope is [#].

I-12 If charges were [ ] distributed in an atom, the forces acting on a positive particle would be [ ] no matter where the particle passed through the atom.

I-26 To understand what an alpha particle is, it is important to know the structure of an atom of helium, $_2He^4$. An atom of $_2He^4$ has [#] particles in its nucleus, [#] protons and [#] neutrons.

I-40 As positively charged alpha particles pass through an [ ], they will be repelled by the [ ] charged nuclei inside the [ ].

I-54 The wide angle deflections of alpha particles in scattering experiments indicated that positive charges are [ ] evenly [ ] in the atom.

rH-7 Atomic masses based on $_8O^{16}$ as a standard are convenient because then an atom's actual mass in [*] [ ] is almost the same as its [ ] number.

(83)

I-10 As a positive particle passes through evenly distributed charges, the forces deflecting it in one direction are [ ] any stronger than the forces [ ] it in any other direction.

I-24 Geiger and Marsden bombarded atoms with [ ] particles. They studied the scattering of the particles to see how much the particles had been [ ] as they passed through the atom.

I-38 In an atom, positive charges are all in the [ ], and electrons orbit at some distance from it; therefore, most of the space occupied by an atom consists of [ ] matter at all.

I-52 The first scattering experiments indicated that the positive charges within an atom are [**].

rh-8·

mass number
127

---

i-11

all (many, several)

---

i-25

(high velocity) alpha particles

---

i-39

smaller
through

---

i-53

positive
center of the atom (nucleus)

rh-7

atomic mass units
mass

i-10

not
deflecting

i-24

alpha
deflected (scattered)

i-38

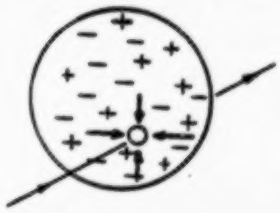
nucleus
no

i-52

not evenly distributed (concentrated in the center (nucleus)) rH-8 The mass of iodine, $_{53}I^{127}$, is 126.945 amu, which is very close to its __________, which is __________.

(98)

I-11 If the charges within an atom were evenly distributed, the forces acting on a positively charged particle passing through the atom would be equal from __________ directions.



I-25 Radioactive isotopes of elements, such as radium and uranium, emit high velocity alpha particles. You will learn later about radioactive isotopes and how they emit __________ __________.

I-39 An atom is very small, but the space occupied by the matter in an atom is even much __________. An alpha particle can easily pass __________ an atom without hitting any matter.

I-53 Rutherford, an associate of Geiger and Marsden, interpreted the appearance of very wide deflections to mean that all of the __________ charges were concentrated at the __________ __________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rH-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER I-11

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER I-25

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER I-39

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER I-53

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UNIT J - Structure of the Nucleus

plus review of Unit I

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number I. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER J-1

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER J-11

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER J-21

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER J-31

END OF UNIT

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START HERE

rl-l Physicists learned less than 60 years ago that an atom consists of a central core, which is called a ☐, and orbiting particles called ☐.

(91)

J-l The discovery that an atom consisted of ☐ in orbit around a central ☐ was important, yet very little was known about a nucleus except that it had a ☐ charge.

J-ll A neutral atom of helium has two electrons. Thus, its nucleus must contain ☐.

J-21 A boron nucleus would have a charge of +5 if it contained ☐ protons. It would also have a charge of +5 if it contained 11 ☐ and 6 ☐.

J-31 The early view that a nucleus was made up of protons and electrons was later proved wrong. Now we know nuclei contain neutrons and ☐, but contain no ☐.

ri-10

through

no

j-10

nucleus

one electron

j-20

protons

j-30

(+) 8

16

rl-l

nucleus
electrons

93

j-l

electrons
nucleus
positive

j-ll

two protons

j-2l

5
protons
electrons

j-3l

protons
electrons

r1-10 Particles can be shot ______ atoms because most of the space occupied by an atom consists of ______ matter at all.

J-10 A neutral atom of hydrogen was known to have one proton in its ______. Thus, it had to have ______ ______ in orbit.

J-20 The nucleus of an atom of the element boron has a charge of +5. It would have a charge of +5 if it simply contained 5 ______.

J-30 The $_8O^{16}$ nucleus was assumed to contain 16 protons and 8 electrons. The 8 electrons would cancel 8 of the positive charges, leaving the nucleus with an overall charge of + ______ and a mass of ______.

rl-2 Because electrons have very little mass compared to the mass of protons and neutrons, most of the ________ of an atom is in the ________.

(95)

J-2 The neutron was not discovered until 1932. Before that, only two kinds of atomic particles were known, negatively charge ________ and positively charged ________.

J-12 Although a helium atom has only 2 positive charges in its nucleus, its nucleus has roughly four times as much mass as the ________ of a hydrogen atom.

J-22 An electron has only $^{1}/_{1840}$ as much mass as a proton; thus, the mass of a proton and an electron together is not much ________ than the mass of a ________ alone.

END OF UNIT

ri-9

scattering

positive charges are (concentrated) in the nucleus

---

j-9

protons

electrons

electron

---

j-19

more

2

---

j-29

16

16

ri-2

mass
nucleus

⑰

j-2

electrons
protons

j-12

nucleus

j-22

greater (larger)
proton

rl-9 Wide deflections of alpha particles in ☐ experiments indicated that, in the atom, all of the ☐** ☐.

(86)

J-9 By knowing the number of ☐ in a nucleus of a neutral atom, it is possible to deduce the number of ☐ in orbit; for each proton, there has to be one ☐.

J-19 To have a positive charge, a helium nucleus would have to contain ☐ protons than electrons. Since it has a charge of + 2, it was thought to have ☐# more protons than electrons.

J-29 The $_{8}O^{16}$ nucleus was once thought to contain ☐# protons. This would account for its mass, but a nucleus with 16 protons would have ☐# positive charges.

rI-3 The existence of the nucleus was discovered in scattering experiments. In these ☐ experiments, ☐ particles, ${}_2He^4$, were shot through atoms.

(99)

J-3 Before neutrons were discovered, it was thought that atomic nuclei contained both protons and electrons. We know now, however, that nuclei never contain ☐.

J-13 Since the mass of a helium nucleus is roughly four times the ☐ of a hydrogen nucleus, it must contain ☐ times as many particles.

J-23 The mass of an electron is very much ☐ than the mass of a proton. The mass of a proton and electron together is hardly more than the mass of a ☐ alone.

ri-8

repelled (deflected) (scattered)
positive charges (positively charged particles)
center (nucleus)

j-8

orbit
different

j-18

plus two (+2)

j-28

9 protons and 5 electrons

ri-3

scattering
alpha

(101)

j-3

electrons

j-13

mass
4

j-23

smaller
proton

H-8 As they pass through atoms, alpha particles are deflected because they are charged and thus are ______ by the concentration of •______ at the ______ of the atom.

J-8 It is possible to determine how many electrons are in ______ around the nuclei of atoms of different elements. Neutral atoms of different elements have ______ numbers of electrons.

J-18 If a helium nucleus contained 4 protons and 2 electrons, the nucleus would have an overall charge of •______.

J-28 A beryllium (ber-ill-ee-um) nucleus has a mass of 9 and a charge of +4. Before neutrons were discovered, it was thought a beryllium nucleus consisted of ••______ ______.

rI-4 Alpha particles are doubly ionized ______ of helium atoms. Since they have a ______ electrical charge, they will be ______ by other positively charged particles.

J-4 To see why it was thought that nuclei contain electrons, it is important to understand the term "neutral atom." A neutral atom has an ______ number of positive and negative charges.

J-14 A helium nucleus must contain 4 particles to account for its ______. But, if it had four protons, it would have a charge of + ______ instead of +2.

J-24 Because the mass of an electron is so small, the mass of four protons together with four electrons would be about ______ ______ as the mass of ______.

---

ri-7

positive

evenly

104

j-7

neutral atom

not a neutral atom (not neutral, negatively charged)

ion

j-17

(+) 2

j-27

7

4

ri-4

nuclei
positive
repelled

---

j-4

equal.

---

j-14

mass
(+) 4

---

j-24

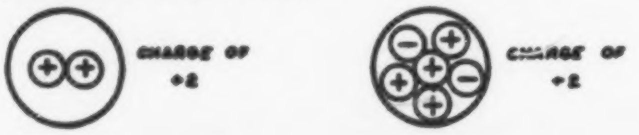
the same
four protons (alone)

---

rl-7 The wide deflections of alpha particles passing through atoms indicated that the ☐ charges in an atom are not ☐ distributed.

J-7 An atom which has 2 + charges and 2 − charges is a ☐. An atom which has 4 + charges and 5 − charges is ☐. It is a negative ☐.

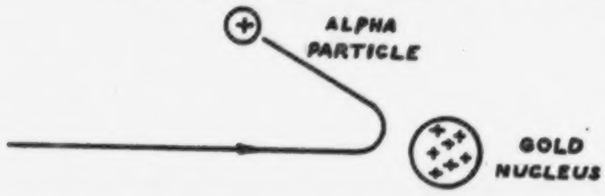
J-17 A helium nucleus would have a charge of + 2 if it contained 2 protons. It would also have a charge of + ☐ if it contained 4 protons and 2 electrons.



J-27 The nucleus of an atom of lithium (lith-ee-um) has a mass of 7 and a charge of + 3. This would be possible if it contained ☐ protons and ☐ electrons.

(107)

rl-5 The positively charged ______ were sometimes widely ______ as they passed through atoms.



J-5 An atom with an ______ number of positive and negative charges is a ______ atom. An atom which has more positive charges than negative charges is not ______.

J-15 On the basis of its mass, a helium nucleus should contain #____ protons, but on the basis of its charge it should contain only #____ protons.

J-25 To explain why a helium nucleus had four times as much mass as a hydrogen nucleus, but a charge of only +2, it was thought that a helium nucleus contained 4 protons and #____ electrons.

---

ri-6

deflected
atoms

---

j-6

ion
positive ion (positively charged ion)

---

j-16

a mass of 4 (4 times the mass of a hydrogen nucleus)
a charge of +2

---

j-26

4
2 electrons

---

ri-5

alpha particles
deflected (scattered)

(109)

j-5

equal
neutral
neutral

j-15

4
2

j-25

2

rI-6 Alpha particles are often [ ] from their original paths when they are shot through the [ ] in the target.

(011)

J-6 An atom with unequal positive and negative charges is called an [ ]. If the atom has lost electrons, it is a [*].

J-16 Since neutrons were not yet discovered, they could not be used to explain why a helium nucleus has [**] but only has [**].

J-26 Before neutrons were discovered, it was thought that a helium nucleus, with a mass of 4 and a charge of +2, consisted of [*] protons and [*].

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rI-6

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER J-6

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER J-16

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER J-26

END OF UNIT

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UNIT K - Discovery of the Neutron

plus review of Unit J

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-19

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-31

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-43

END OF UNIT

START HERE

J-1 A neutral atom has as many ☐ charges as it has ☐*.

(115)

K-7 When Rutherford bombarded nitrogen with alpha particles, he observed the ☐ of the alpha particles.

K-19 A jet plane produces vapor trails which we can see even if the plan is so high it ☐**. Vapor trails let us ☐ where the plane has been.

K-31 Chadwick found that the new particles that were emitted were very penetrating, which means that they can easily ☐ through matter.

K-43 Chadwick next determined that neutrons, which have no ☐, have approximately the same mass as a ☐.

k-6

through
atom
nucleus

---

k-18

paths
(Wilson) cloud chamber

---

k-30

alpha particles (beryllium atoms)
beryllium atoms (alpha particles)

---

k-42

neutrons
not charged (electrically neutral)
penetrating

---

rj-1

negative (positive)
positive charges (negative charges)

(117)

---

k-7

scattering

---

k-19

cannot be seen
see (know)

---

k-31

penetrate (pass)

---

k-43

charge
proton

K-6 An alpha particle can pass ________ an ________, but it cannot pass through a ________.

K-18 A cloud chamber makes the paths of atomic particles visible. Although the particles themselves are too small to be seen, their ________ may be observed in a ________ ________.

K-30 Chadwick bombarded beryllium atoms with alpha particles. An unknown particle was emitted when the ________ ________ collided with the ________.

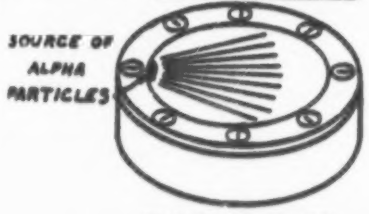
K-42 When alpha particles are used to bombard beryllium, ________ are emitted. These particles are ________ ________ and thus are very ________.

rJ-2 An atom that has been ionized has unequal numbers of positive and negative charges; and thus it is not a ________ atom.

(119)

K-8 When nitrogen was bombarded with alpha particles, some protons emerged. Apparently, the ________ somehow caused some ________ to be knocked loose.

K-20 Atomic particles moving through a Wilson ________ ________ produce tracks that reveal their paths even though the particles are so small we cannot ________ ________.



CLOUD CHAMBER

K-32 Particles that are very penetrating pass easily through matter. Alpha particles are not very ________, they do not easily ________.

K-44 Chadwick's discovery of the neutron changed the older view that atomic nuclei consist of ________ ________.

k-5

atoms

k-17

new nucleus
cloud chamber

k-29

neutron
nucleus

k-41

neutral

rj-2

neutral

---

k-8

alpha particles

protons

---

k-20

cloud chamber

see them

---

k-32

penetrating

pass through matter

---

k-44

protons and electrons

K-5 An alpha particle can pass through an atom by going between electrons. In scattering experiments, $_2He^4$ particles pass through ☐ in this way.

K-17 Rutherford's explanation that a ☐ was formed can be supported with a Wilson cloud chamber, since the results of the collision could be observed in a Wilson ☐ ☐.

K-29 In 1932, Chadwick, an associate of Rutherford, discovered the neutral particle, the ☐, thus leading to our present knowledge of the structure of the ☐ of an atom.

K-41 The uncharged particles were named neutrons. "Neu" meant uncharged or ☐.

rJ-3 A positive ion is an atom that has ☐ an electron. An atom that has gained an electron is called a ☐ ☐.

(123)

K-9 Rutherford then tried to determine where the protons came from. One possibility was that the protons were being knocked out of the ☐ of nitrogen atoms.

K-21 Particles that are rapidly ☐ through a cloud chamber will leave tracks. Protons would leave ☐, for example, if they are knocked loose in a collision.

K-33 An alpha particle is not very penetrating because it is charged and, thus, it is either attracted or ☐ by other charged particles in its path which ☐ it down in speed.

K-45 According to the older view, a nucleus of ${}_2He^4$ was thought to consist of ☐ protons and ☐ electrons. We now know it consists of ☐ ☐.

124

k-4

nucleus

k-16

nucleus

proton

k-28

nuclear reactions

neutron

k-40

not

neutral

rj-3

lost
negative ion

(125)

---

k-9

nucleus

---

k-21

moving
tracks

---

k-33

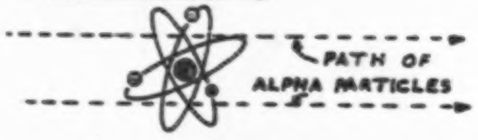
repelled
slow

---

k-45

4
2
2 protons and 2 neutrons

K-4 The particles in a nucleus are very close together, but electrons are widely spaced. An alpha particle can pass between electrons, but not through the ☐.



K-16 If the proton had been knocked loose from one of the colliding nuclei, there would then be three particles: the remains of the alpha particle, the remains of the $_7N^{14}$ ☐, and the ☐.

K-28 Scattering experiments led to Rutherford's observation of ☐, which led in turn to the discovery of the uncharged nucleon, the ☐.

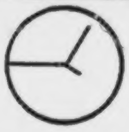
K-40 Since the newly discovered particles were very penetrating, they probably were ☐ charged, that is, they were electrically ☐.

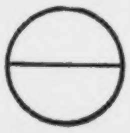
(127)

J-4 If the number of orbiting electrons exactly equals the number of protons, the atom is ________. Both the number of protons and electrons is then indicated by the ________ number.

K-10 The protons could have been knocked out of nitrogen nuclei. They also could have been knocked out of one of the * ________ which struck a nitrogen nucleus.

K-22 The figure at the left shows that a collision has occurred. The figure at the right does not show ** ________.





K-34 As a charged particle passes near other * ________, it will be either attracted or repelled by them and be ________ down in speed.

K-46 The correct structure of the nucleus was finally determined when the neutron was discovered. Nuclei contain only two kinds of particles, ________ and ________.

3

k-3

nuclear
scattering (deflection)

k-15

2
new nucleus

k-27

nuclear reaction
a proton and a new nucleus

k-39

charged
attracted or repelled
not

rj-4

neutral
atomic

(129)

---

k-10

alpha particles

---

k-22

that a collision has occurred

---

k-34

charged particle
slowed

---

k-46

protons (neutrons)
neutrons (protons)

K-3 The physicist, Rutherford, was the first to observe ________ reactions. At the time, he was studying the ________ of alpha particles as they passed through atoms of nitrogen.

K-15 If Rutherford's explanation was correct, a collision between a $_2He^4$ and $_7N^{14}$ nucleus would result in only #________ particles, a *________ and a proton.

K-27 When a $_2He^4$ strikes a nitrogen nucleus, a *________ occurs. The two particles produced are **________.

K-39 Only ________ particles will be slowed by being *________ by other charged particles. Very penetrating particles, then, are ________ charged.

K-3 The physicist, Rutherford, was the first to observe ________ reactions. At the time, he was studying the ________ of alpha particles as they passed through atoms of nitrogen.

K-15 If Rutherford's explanation was correct, a collision between a $_2He^4$ and $_7N^{14}$ nucleus would result in only •________ particles, a •________ and a proton.

K-27 When a $_2He^4$ strikes a nitrogen nucleus, a •________ ________ occurs. The two particles produced are ••________ ________.

K-39 Only ________ particles will be slowed by being •________ by other charged particles. Very penetrating particles, then, are ________ charged.

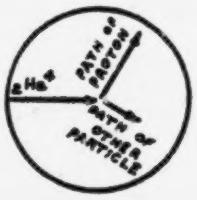
---

rJ-5 A neutral $_2He^4$ atom has #______ orbiting electrons, and a neutral $_6O^{17}$ atom has #______ orbiting electrons.

(131)

K-11 When an alpha particle, $_2He^4$, collided with a $_7N^{14}$ nucleus, a proton was emitted. Rutherford thought it possible that a proton had been knocked out of either the **______ ______.

K-23 As shown in the figure, if a *______ ______ is used to study the tracks produced when an alpha particle strikes a $_7N^{14}$ nucleus, it will be seen that only #______ particles leave the collision.



K-35 A moving charged particle will *______ when it passes near other charged particles. Thus, charged particles are not very ______.

K-47 There are two kinds of nucleons; ______ and ______, each with approximately the same amount of ______. There are ______ electrons in an atomic nucleus.

k-2

alpha particles

132

---

k-14

proton

new

---

k-26

nuclear reaction

new nucleus

---

k-38

attracted or repelled (slowed down)

---

rj-5

2
6

k-11

$_7N^{14}$ nucleus or the $_2He^4$ nucleus (alpha particle)

k-23

(Wilson) cloud chamber
2

k-35

slow down
penetrating

k-47

protons (neutrons)
neutrons (protons)
mass
no (zero)

K-2 Nuclear reactions were first observed during scattering experiments. Scattering occurs when atoms are bombarded with $_2He^4$ nuclei, which are called ________.

K-14 The only explanation left was that the collision resulted in the formation of a new nucleus along with the one ________. The ________ nucleus was neither a $_7N^{14}$ nor a $_2He^4$ nucleus.

K-26 Rutherford surmised that when an alpha particle and $_7N^{14}$ nucleus collide, a ________ occurs which results in the formation of a proton and a ________.

K-38 The newly discovered particles were much more penetrating than alpha particles. This suggested that the new particle was not ________ by charged particles in its path.

END OF UNIT

rJ-6 Before the neutron was discovered, nuclei were thought to contain ________ and electrons. We know now that nuclei contain protons and neutrons, but never ** ____________ ________.

(135)

K-12 Experiments indicated that the protons had far greater velocity than would have been possible if they had been * ______ ________ either the $_2He^4$ or the $_7N^{14}$ nucleus.

K-24 Rutherford identified two particles resulting from the collision of a $_2He^4$ and $_7N^{14}$ nucleus. One particle was a ______ and the other was a * ____________, formed when the $_2He^4$ and $_7N^{14}$ combined.

K-36 Protons and electrons are charged particles; they are not very penetrating because ** ________________ ____________.

K-48 The nucleus of a lithium atom, $_3Li^7$, has a mass of 7 and a charge of + 3. We now know the nucleus contains * ____ protons and * __________.

k-1

reaction

---

k-13

velocity (speed)
not

---

k-25

nucleus
nuclear reaction

---

k-37

neutral (uncharged)
charged

---

k-49

no
(also) has a mass of approximately 1 amu

rj-6

protons
contain any electrons

k-12

knocked out of (knocked loose from)

k-24

proton
new nucleus

k-36

they are slowed (attracted and repelled) as they pass other charged particles

k-48

3
4 neutrons

K-1 Neutrons were discovered during experiments on nuclear (new-klee-er) reactions. A nuclear ________ occurs when the structure of the nucleus of an atom is changed.

K-13 Because the protons had such a high ________, Rutherford was able to determine that they could ________ have been knocked loose from the $_7N^{14}$ or $_2He^4$ when they collided.

K-25 A nuclear reaction means there has been a change in the structure of a ________. When two particles combine into a new nucleus, a ________ has occurred.

K-37 A charged particle is not as penetrating as a ________ particle because a charged particle is slowed by the attraction and repulsion of other ________ particles.

K-49 A single proton has a positive charge and a mass of approximately 1 amu. A single neutron has ________ charge and it ________.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-1

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-13

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-25

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-37

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER K-49

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UNIT L - Nuclear Reactions

plus review of Unit K

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number l. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER L-5

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER L-19

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER L-33

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER L-47

END OF UNIT

← START HERE

rK-1 When a ☐ reaction occurs, there is a change in the structure of a ☐.

L-5 As you remember, an alpha particle is a helium nucleus with a charge of +2 and a mass of 4. In symbols, an alpha particle is written ☐.

L-19 ${}_2He^4 + {}_7N^{14}$ are the particles before one type of nuclear reaction. The Z and A numbers tell us that before the reaction there was a total of nine protons and ☐ nucleons.

L-33 As you remember, the particles Chadwick observed were very penetrating, because they were not attracted or repelled as they passed through atoms. These particles are called ☐.

L-47 There were 16 ☐ before this reaction, so there must be ☐ after it. Since ${}_6C^{12}$ has ☐ nucleons, the other particle has ☐ nucleons.

$${}_1p^1 + {}_7N^{15} \longrightarrow {}_6C^{12} + \text{(particle)}$$

1-4

protons (positive charges)
mass (A)

1-18

atomic
13
mass
27

1-32

nuclear reaction
particle

1-46

Z (A)
A (Z)

---

rk-1

nuclear
nucleus

(145)

1-5

$_2He^4$

1-19

18

1-33

neutrons

1-47

nucleons
16 nucleons
12
4

L-4 . The atomic number, which is at the left of the symbol, indicates the number of [ ] in the nucleus. The total number of nucleons is indicated by the [ ] number at the right.

HYDROGEN $_1H^2$

L-18 The atomic and mass numbers used to identify isotopes are important. For example, for $_{13}Al^{27}$ the Z, or [ ] number is [#], and the A, or [ ] number is [#].

L-32 Chadwick bombarded beryllium with alpha particles. A [*] occurred and, in addition to protons, he also found that another kind of [ ] was emitted.

L-46 By knowing portions of any nuclear reaction equation, the remaining portions can be found by balancing the [$] and [$] numbers.

rK-2 Rutherford discovered ______________ while doing a scattering experiment. He bombarded nitrogen ${}_7N^{14}$ with ______________, and a proton was emitted.

(147)

L-6 We use the symbol p to mean proton and n to mean neutron. By writing ${}_1p$, we indicate that a proton has a charge of ______; by ${}_0n$ we indicate that ______________ ______________.

L-20 From the Z and A numbers, you know that before the reaction ${}_2He^4 + {}_{13}Al^{27}$ there were ______ nucleons, of which ______ were protons and ______ were neutrons.

L-34 This is the equation for the nuclear reaction that resulted in the discovery of the neutron. There are ______ nucleons before the reaction.

$${}_2He^4 + {}_4Be^9 \longrightarrow$$

L-48 ${}_1p^1 + {}_7N^{15} \longrightarrow {}_6C^{12}$ + (particle). The particle emitted consists of ______ nucleons, of which ______ are protons. You already know that this particle, ______, is called an ______________ ______________.

1-3

hydrogen
isotopes
hydrogen

148

1-17

alpha particle (helium nucleus)
proton

1-31

the total of the mass numbers (of the particles) before the reaction

1-45

protons
twelve nucleons

rk-2

nuclear reactions
alpha particles

(149)

I-6

I (plus I)
a neutron has no charge (has a charge of zero)

I-20

31
15
16

I-34

13

I-48

4
2
$_2He^4$
alpha particle

L-3 We use symbols to represent elements and isotopes of elements. For example, $_1H$ represents the element ________. and $_1H^1$, $_1H^2$, and $_1H^3$ represent the three ________ of ________.

L-17 The equation $_2He^4 + {}_7N^{14} \longrightarrow {}_1p^1 +$ (a nucleus), means that an *________ unites with a $_7N^{14}$ nucleus and becomes one ________ plus a nucleus.

L-31 In a nuclear reaction the total of the mass numbers of the particles after the reaction equals **________ ________.

L-45 Before the reaction, $_1p^1 + {}_7N^{15}$, there were sixteen nucleons, of which 8 were ________. The $_6C^{12}$ nucleus contains a total of *________, of which six are protons.

$$_1p^1 + {}_7N^{15} \longrightarrow {}_6C^{12} + \text{(particle)}$$

(151)

rK-3 When an alpha particle struck a ${}_7N^{14}$ nucleus, two particles resulted, a ______ and a new ______. Because it had such a high ______, the proton could not have been simply knocked loose.

L-7 Protons and neutrons both have a mass number of one. The complete symbol for a neutron, then, is ${}_0n^1$, and the complete symbol for a proton is ______.

L-21 For a nuclear ______, the number of nucleons before the reaction is always the same as the ______ ______ after the reaction.

L-35 ${}_2He^4$ plus ${}_4Be^9$ have a total of ______ nucleons, of which ______ are protons, and ______ are neutrons.

L-49 ${}_0n^1 + {}_8O^{16} \longrightarrow {}_7N^{16} +$ ______. The particle emitted from this nuclear reaction is a ______.

I-2

mass
positive
is neutral (has no charge)

I-16

become

I-30

the total of atomic numbers to the right of the arrow

I-44

16
8

(153)

rk-3

proton
nucleus
velocity

1-7

${}_{1}p^{1}$

1-21

reaction
number of nucleons

1-35

13
6
7

1-49

${}_{1}p^{1}$
proton

L-2 Protons and neutrons have approximately the same amounts of ________. A proton has a ________ charge, a neutron ** ________.

L-16 a + b ⟶ c + d. The arrow means "become." This equation means that a and b unite and ________ c and d.

L-30 In a reaction equation, the total of the atomic numbers to the left of the arrow is the same as ** ________ ________.

L-44 When $_1p^1$ unites with $_7N^{15}$, a carbon nucleus $_6C^{12}$, is formed. There were ________ nucleons before the reaction, of which ________ were protons.

$$_1p^1 + {}_7N^{15} \longrightarrow {}_6C^{12} + \text{(particle)}$$

END OF UNIT

rK-4 The results of the collision between a ${}_2\mathrm{He}^4$ and ${}_7\mathrm{N}^{14}$ nucleus can be studied by observing the [ ] produced by the particles in a Wilson [*].

(155)

L-8 The complete symbol for a neutron is [$]; the complete symbol for a [ ] is ${}_1p^1$. The symbol for an alpha particle is [$].

L-22 Nucleons mean both [*]. The total number of nucleons in a nucleus, minus the number of protons, indicates the number of [ ].

$$ {}_8\mathrm{O}^{17} = \begin{array}{l} 17 \text{ nucleons} \\ \underline{8 \text{ protons}} \\ 9 \text{ neutrons} \end{array} $$

L-36 Six protons entered the reaction. Since no charged particles were emitted, the new nucleus has an [*] of 6, which identifies the [ ] carbon, symbol C.

$$ {}_2\mathrm{He}^4 + {}_4\mathrm{Be}^9 \longrightarrow {}_0n^1 + \text{(new nucleus)} $$

L-50 In this nuclear reaction, the particle used to bombard boron atoms, ${}_5\mathrm{B}^{10}$, was a [ ].

$$ [\$ \quad] + {}_5\mathrm{B}^{10} \longrightarrow {}_3\mathrm{Li}^7 + {}_2\mathrm{He}^4 $$

I-1

protons and neutrons

I-15

particles after the reaction

I-29

element
$_8O^{17}$

I-43

nuclear reactions
proton

I-57

nuclear reaction
elements (isotopes)
isotopes (elements)

rk-4

tracks
cloud chamber

I-8

$_0n^1$
proton
$_2He^4$

I-22

protons and neutrons
neutrons

I-36

atomic number (positive charge)
element

I-50

neutron
$_0n^1$

L-1 Nuclei consist of two kinds of particles; * ________ ________.

L-15 A nuclear reaction is written: $a + b \longrightarrow c + d$. The symbols to the left of the arrow represent the particles before the reaction. The symbols to the right represent the ** ________ ________.

L-29 The atomic number 8 identifies the ________ oxygen, symbol O. For the new nucleus, $Z = 8$ and $A = 17$. Thus, the complete symbol for the new nucleus is $ ________.

L-43 Other particles besides ${}_2\text{He}^4$ can be used to bombard atoms and cause * ________. ${}_1p^1 + {}_3\text{Li}^7$ indicates that lithium, ${}_3\text{Li}^7$, was bombarded by a ________.

L-57 Rutherford discovered that when he bombarded atoms with particles, a * ________ may occur. In this way, it is possible to change nuclei to different ________ or to different ________.

rK-5 Scattering experiments led to Rutherford's discovery that nuclei change during a [•], which led, in turn, to the discovery of the uncharged nucleon, the [ ].

(159)

L-9 The symbol ${}_1H^1$ represents the nucleus of hydrogen which consists of only [•]. Thus, both the symbol ${}_1H^1$ and the symbol ${}_1p^1$ represent a single [ ].

L-23 Before the reaction ${}_2He^4 + {}_7N^{14} \longrightarrow$, there was a total of [#] nucleons, of which [#] were protons and [#] were [ ].

L-37 After the reaction, 13 nucleons must be accounted for. Since one neutron was emitted, [#] nucleons must be in the ${}_6C$ nucleus, thus, its complete equation is: ${}_2He^4 + {}_4Be^9 \longrightarrow {}_0n^1 +$ [$].

L-51 In some nuclear reactions, no free particle is emitted. For example, ${}_0n^1 + {}_8O^{16} \longrightarrow {}_8O^{17}$. Here, a [ ] combined with an ${}_8O^{16}$ nucleus to produce a different [ ] of the element oxygen.

rk-10

3

3

4 neutrons

091

I-14

nuclear

I-28

oxygen

$_8O$

I-42

$_{15}P^{30}$

I-56

spectrograph

mass

isotopes

rk-5

nuclear reaction
neutron

(161)

1-9

one proton
proton

1-23

18
9
9
neutrons

1-37

12
$_6C^{12}$

1-51

neutron
isotope

rK-10 The nucleus of lithium, ${}_3\text{Li}^7$, has a mass of 7 amu and a charge of + [#]. It consists of [#] protons and [*].

L-14 Symbols can be used to write equations representing nuclear reactions. You have learned how the neutron was discovered when it was emitted in a [ ] reaction.

L-28 The Z number of the new nucleus is 8. As shown in the table, the new nucleus must be an isotope of the element [ ], symbol [$].

Element	Symbol
Carbon	${}_6C$
Nitrogen	${}_7N$
Oxygen	${}_8O$
Fluorine	${}_9F$

L-42 If ${}_2\text{He}^4$ unites with a ${}_{13}\text{Al}^{27}$ nucleus and a neutron is emitted, a nucleus of the element phosphorus, P, results. The equation is:

$${}_2\text{He}^4 + {}_{13}\text{Al}^{27} \longrightarrow {}_0n^1 + [\$].$$

L-56 With his mass [ ], Thomson discovered that atoms of the same element did not all have the same [ ], that is, elements may have several [ ].

rK-6 Chadwick found that the newly discovered particles were very penetrating, which means they easily passed through $\boxed{}$. This suggested that the particles have no $\boxed{}$.

(163)

L-10 The symbol ${}_5B^{10}$ tells us that a boron nucleus contains 5 $\boxed{}$, that is, five positive $\boxed{}$, and that altogether it contains a total of ten $\boxed{}$.

L-24 Together, ${}_2He^4$ and ${}_7N^{14}$ have 18 nucleons. Since one proton is emitted in this nuclear reaction, the new nucleus must contain the remaining $\boxed{\#}$ nucleons.

$$ {}_2He^4 + {}_7N^{14} \longrightarrow {}_1p^1 + \text{(a nucleus)} $$

L-38 The complete equation for this nuclear reaction in which a neutron is emitted is:

$$ {}_2He^4 + {}_4Be^9 \longrightarrow \boxed{\$} + {}_0n^1 $$

L-52 One nuclear reaction in which a new nucleus is formed but no free particle is emitted is ${}_0n^1 + {}_7N^{14}$. The new nucleus is a different $\boxed{}$ of the original element, nitrogen, and is written as $\boxed{\$}$.

rk-9

protons and neutrons
electrons

I-13

each particle is a single nucleon

I-27

8
17

I-41

31
nucleons
30

I-55

element
isotope (atom)

rk-6

matter
charge

(165)

1-10

protons
charges
nucleons (particles)

1-24

17

1-38

$_6C^{12}$

1-52

isotope
$_7N^{15}$

rK-9 The discovery of the neutron changed the older view that a nucleus contained protons and electrons. We know now that nuclei contain * ____________ but no ____________.

L-13 The mass number in the symbols ${}_{1}p^{1}$ and ${}_{0}n^{1}$ indicate that ** ____________________.

L-27 By determining how many charges and nucleons went into a nuclear reaction we can determine what the new nucleus must be. In this reaction, the new nucleus has Z = ______ and A = ______.

$$ {}_{2}\mathrm{He}^{4} + {}_{7}\mathrm{N}^{14} \longrightarrow {}_{1}p^{1} + \text{(new nucleus)} $$

L-41 There were a total of ______ nucleons before this reaction. Since the neutron is one of these ____________, the remaining ______ nucleons must be in the new nucleus.

$$ {}_{2}\mathrm{He}^{4} + {}_{13}\mathrm{Al}^{27} \longrightarrow {}_{0}n^{1} + \text{(new nucleus)} $$

L-55 If a nucleus absorbs a neutron, it does not change to a nucleus of a different ____________, but it does become a different ____________ of the original element.

rK-7 The particle discovered by Chadwick has about the same ☐ as a proton, but is electrically ☐. These particles were named ☐.

(167)

L-11 The symbols $_1p^1$ and $_0n^1$ are like the symbol $_5B^{10}$, in that they indicate both the number of ☐ and the total number of ☐ making up the particle.

L-25 Neither nucleons or charges ever disappear in a nuclear reaction. The total positive charges and total nucleons are always the ☐ before and after a ☐.

L-39 The equation $_2He^4 + {}_{13}Al^{27} \longrightarrow$ means that an ☐ combines with an aluminum ☐ in a ☐.

L-53 If a nucleus absorbs a proton, its Z number increases and it becomes a nucleus of a different ☐. Whenever the number of protons in a nucleus is changed, it is no longer the same ☐.

rk-8

nuclear reaction
nucleus
neutron

1-12

a single nucleon

1-26

9
8

1-40

neutron
15

1-54

protons (charges)
a different element

rk-7

mass
neutral
neutrons

169

I-11

protons (charges)
nucleons (particles)

I-25

same
nuclear reaction

I-39

alpha particle (helium nucleus)
nucleus
nuclear reaction

I-53

element
element

rK-8 When $_2He^4$ combined with a $_4Be^9$ nucleus, a ☐ ☐ occurred and a new ☐ was formed. During the reaction, an uncharged particle, the ☐ was emitted.

QLI

L-12 The mass number in the proton symbol $_1p^1$ indicates the particle is a single nucleon. The number 1 in the symbol $_0n^1$ indicates this particle is also ☐.

L-26 A total of ☐ protons entered this reaction. Since one proton was emitted, the new nucleus must contain the remaining ☐ charges.

$$_2He^4 + {}_7N^{14} \longrightarrow {}_1p^1 + \text{(a nucleus)}$$

L-40 In this reaction, a ☐ and a new nucleus result. The new nucleus must contain ☐ protons.

$$_2He^4 + {}_{13}Al^{27} \longrightarrow {}_0n^1 + \text{(new nucleus)}$$

L-54 A nucleus is changed to a nucleus of a different element if the number of ☐ is changed. If a nucleus absorbs a proton, it becomes a nucleus of ☐.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rK-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER L-12

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER L-26

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER L-40

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER L-54

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173

UNIT M - Nuclear Mass and Energy

plus review of Unit L

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER M-2

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER M-14

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER M-26

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER M-38

END OF UNIT

START HERE

rL-1 The symbol for an [*] is $_2He^4$. The Z number of $_2He^4$ is [#], which means [**].

(175)

M-2 All atomic particles have [ ]. By careful measurement, it is possible to determine the [ ] of the particles before and after a [ ] reaction.

M-14 If a low velocity particle enters a nuclear reaction and another particle is emitted at a much higher velocity, some [ ] has been released in the reaction.

M-26 In the mass-energy equation, written [$], E stands for amount of energy, and m stands for amount of [ ].

M-38 Energy measured in electron volts is a large number. For convenience, it is written as millions of electron volts. Three million electron volts is written 3 Mev. Mev means [*].

m-1

mass

m-13

nuclear reaction

energy

m-25

mass-energy

mc^2

mass

m-37

electron volts

rl-l

alpha particle
2
there are 2 protons (2 positive charges) in it

m-2

mass
mass
nuclear

m-14

energy

m-26

$E=mc^2$
mass

m-38

million electron volts

M-1 Nuclei are made of particles of matter. These particles all have [ ].

M-13 When energy is released during a [*] [ ], this [ ] is in the motion, or velocity, of the particles involved.

M-25 Einstein's [*] equation, E=[$], indicates how much energy will be released when a specific amount of [ ] disappears in a nuclear reaction.

M-37 In nuclear reactions, energy is measured in electron volts. The amount of energy is usually very large and is measured in millions of [*].

---

rL-2 The symbol for a proton is $_1p^1$ and the symbol for a ______ is $_0n^1$. The symbol for an alpha particle is $______.

(179)

M-3 You might expect that the total mass of the particles resulting from a nuclear reaction would be exactly *______ ______ the total mass of the original particles.

M-15 An alpha particle moving at a high velocity has more energy than an alpha particle **______ ______. Particles with different velocities have different amounts of ______.

M-27 In the equation $E=mc^2$, c stands for the speed of light -- about 186,000 miles per second. c^2 is nearly 35,000,000,000, which is a very ______ number. Thus, E must also be *______ ______, even if m is small.

M-39 The unit used to measure ______ in a nuclear reaction is the Mev. One $______ means one *______ ______.

m-11

element

changes to a new isotope

---

m-12

low velocity

---

m-24

mass

$E = mc^2$

---

m-36

energy

some energy has been released (some mass has disappeared)

---

rl-2

neutron
$_2He^4$

m-3

the same as (equal to)

m-15

moving at a low velocity
energy

m-27

large
very large

m-39

energy
Mev
million electron volts

rL-11 If the Z number changes in a nuclear reaction, the nucleus changes to a new ________. If the A number changes, the nucleus ** ________________.

M-12 A high velocity particle has more energy than a * ________________ particle.

M-24 Einstein's mass-energy equation is written $E=mc^2$. The relationship between ________ and energy is indicated in the equation $ ________.

M-36 We can measure the mass before and after a nuclear reaction. If the mass is greater after the reaction, some ________ has been lost; if the mass is less, ** ________________ ________________.

END OF UNIT

rL-3 The nuclear reaction ${}_2He^4 + {}_7N^{14} \longrightarrow {}_1p^1 + {}_8O^{17}$ means that an • ____________ united with a nitrogen nucleus to form oxygen, and a ____________ was emitted.

(183)

M-4 Careful measurements have shown that the total mass before a reaction is not equal to the •• ____________ ____________. Thus, there is a ____________ in the total amount of mass during a nuclear reaction.

M-16 Energy is not always released in nuclear reactions. In some cases there is less energy after a reaction, which means that some ____________, not mass, has disappeared.

M-28 Because c^2 is such a large number, the equation $ ____________ indicates that a very small amount of mass is equivalent to a very • ____________.

M-40 In the nuclear reaction, ${}_3Li^7 + {}_1p^1$, the .019 amu of mass which disappears during the reaction was converted to ____________. This amount of mass converts to 17.7 $ ____________ of energy.

m-10

6

12

---

m-11

energy

reaction

---

m-23

mass-energy equation

---

m-35

mass

released as energy (converted to energy)

---

m-47

not

change in the structure of atomic nuclei

rl-3

alpha particle
proton

(185)

---

m-4

total mass afterwards
change

---

m-16

energy

---

m-28

$E=mc^2$
large amount of energy

---

m-40

energy
Mev

rL-10 $_2He^4 + _4Be^9 \longrightarrow _0n^1$ + (a nucleus). The Z number of the new nucleus is [#] and its A number must be [#].

M-11 In a nuclear reaction, [ ] is released in the form of motion of the particles resulting from the [ ].

M-23 Einstein's equation is called the mass-energy equation. The [*] indicates how much mass is equivalent to a given amount of energy.

M-35 $_3Li^7 + _1p^1$ results in a nuclear reaction in which 8.025 amu is reduced to 8.006 amu. The difference, approximately .019 amu, represents the amount of [ ] that has been [**].

M-47 A chemical reaction does [ ] involve a change in the structure of nuclei, but in every nuclear reaction there is a [**].

(187)

rL-4 In the reaction, ${}_2He^4 + {}_{13}Al^{27} \longrightarrow$, there are #_____ nucleons before the reaction, of which #_____ are protons, and #_____ are neutrons.

M-5 The total mass involved may either increase or ________ during a nuclear reaction. Such changes in mass can be detected by careful ____________.

M-17 When mass disappears, ________ is released, and when energy ____________, some mass is produced.

M-29 If one gram of matter (less than half the weight of a dime) were converted to energy, the largest aircraft carrier could be driven once around the world by the ________ that would be released.

M-41 Cockcroft and Walton, using the ${}_3Li^7 + {}_1p^1$ reaction, found that Einstein's ____________ equation accurately predicted the amount of energy that was released when .019 amu __________.

rl-9

neutron
nuclear reaction
alpha particles

---

m-10

energy
released

---

m-22

mass (energy)
energy (mass)

---

m-34

mass
energy

---

m-46

converted to energy (decreased in a reaction)
mass
energy

rl-4

31

15

16

189

m-5

decrease

measurement

m-17

energy

disappears

m-29

energy

m-41

mass-energy

disappeared

rL-9 The very penetrating particle discovered by Chadwick was the ________. It was emitted in a ________ ________ that occurred when beryllium was bombarded by ________.

061

M-10 The mass and the energy present before and after a nuclear reaction can be determined. If mass disappears in a reaction, some ________ will be ________.

M-22 The precise relationship between ________ and ________ was first described by Einstein.

M-34 When an amount of mass disappears in a nuclear reaction, that amount of ________ has been converted into ________.

M-46 In a nuclear reaction, energy is released when some of the mass is ________. The energy released in a chemical reaction does not result from the conversion of ________ into ________.

rL-5 Before the reaction, ${}_{2}\mathrm{He}^{4} + {}_{13}\mathrm{Al}^{27} \longrightarrow$, there are [#] nucleons, so there must be [*] after the reaction.

(191)

M-6 ${}_{2}\mathrm{He}^{4} + {}_{4}\mathrm{Be}^{9} \longrightarrow {}_{6}\mathrm{C}^{12} + {}_{0}n^{1}$ is the equation for the [*] that resulted in the discovery of the [ ].

M-18 Either mass or energy may disappear in a [*] [ ]; when mass disappears, [ ] is always released; when energy disappears, [ ] is always produced.

M-30 Einstein's mass-energy equation was first verified in 1932 when it was found that the equation [$] accurately stated the relationship between [*].

M-42 Since [ ] is released in the reaction, the complete equation is written ${}_{3}\mathrm{Li}^{7} + {}_{1}p^{1} \longrightarrow {}_{2}\mathrm{He}^{4} + {}_{2}\mathrm{He}^{4} + \text{energy}$. Energy was released because some [**] [ ].

rl-8

$_{8}O^{17}$

---

m-9

disappears

energy that will be released

---

m-21

specific amount

released (produced)

---

m-33

less mass

---

m-45

not

mass (energy)

energy (mass)

rl-5

31

31 nucleons

(193)

m-6

nuclear reaction

neutron

m-18

nuclear reaction

energy

mass

m-30

$E=mc^2$

mass and energy

m-42

energy

some mass disappeared (some mass was converted to energy) rL-8 $_2\mathrm{He}^4 + {}_7\mathrm{N}^{14} \longrightarrow {}_1\mathrm{p}^1$ + (an oxygen nucleus). The complete symbol for the oxygen nucleus (symbol O) in this reaction is ☐.

M-9 In any nuclear reaction where mass ☐, energy will be released. The greater the amount of mass that disappears, the more the ☐ ☐.

M-21 There is a precise relationship between mass and energy. When a specific amount of mass disappears, a ☐ ☐ of energy will be ☐.

M-33 The mass of $_3\mathrm{Li}^7 + {}_1\mathrm{p}^1$ is 8.025 amu. The mass of two alpha particles is 8.006 amu. There is ☐ after the reaction than there was before.

$_3\mathrm{Li}^7$ = 7.017 amu $_1\mathrm{p}^1$ = 1.008 amu	$_2\mathrm{He}^4$ = 4.003 amu $_2\mathrm{He}^4$ = 4.003 amu
Before = 8.025 amu	After = 8.006 amu

M-45 A chemical reaction converts energy from one form to another, but it does ☐ result in a change in either the amount of ☐ or the amount of ☐ involved.

rL-6 The number of nucleons and number of positive charges is always the ______ after a reaction as it was * ______ ______.

$${}_2He^4 + {}_{13}Al^{27} \longrightarrow {}_0n^1 + {}_{15}P^{30}$$

M-7 In this nuclear reaction, careful measurements have shown that ${}_2He^4 + {}_4Be^9$ have more mass than ${}_6C^{12} + {}_0n^1$. There is ______ mass after the reaction than before it.

$${}_2He^4 + {}_4Be^9 \longrightarrow {}_6C^{12} + {}_0n^1$$

M-19 Mass can be converted to energy, and energy can be * ______ in a nuclear reaction.

M-31 In 1932, Cockcroft and Walton very carefully measured the changes in ______ and ______ that occur during a * ______.

M-43 Einstein's mass-energy equation indicates the precise relationship between * ______. A very small amount of mass is equivalent to ** ______ ______.

rl-7

9

8

m-8

disappears (decreases)

m-20

mass

can be changed into energy

m-32

nuclear reaction

$_1p^1$

$_2He^4$

m-44

form of energy

rl-6

same
before the reaction

(197)

---

m-7

less

---

m-19

converted to mass

---

m-31

mass (energy)
energy (mass)
nuclear reaction

---

m-43

mass and energy
a very large amount of energy

rL-7 $_2He^4 + {}_7N^{14} \longrightarrow {}_1p^1$ + (a nucleus). Since there were [#] protons before the reaction and one proton was emitted, the new nucleus must contain [#] protons.

(861)

M-8 Mass disappears in the nuclear reaction, $_2He^4 + {}_4Be^9 \longrightarrow {}_6C^{12} + {}_0n^1$. In this reaction, when mass [ ], energy is released.

M-20 Neither mass nor energy can be created nor destroyed, but energy can be changed into [ ], and mass [••] [ ] in nuclear reactions.

M-32 Cockcroft and Walton bombarded lithium, $_3Li^7$, with protons, $_1p^1$. This [•] produced two alpha particles. The equation is written [$] + $_3Li^7 \longrightarrow {}_2He^4$ + [$].

M-44 In a chemical reaction, energy is converted from one form of energy to another [•]. A chemical reaction may also change the appearance of the substances involved.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rL-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER M-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER M-20

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER M-32

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER M-44